

**AMENDMENTS TO THE CLAIMS:**

This listing of the claims will replace all prior versions, and listings, of the claims in this application.

**Listing of Claims:**

1. (Currently Amended) A code division, multiple access (CDMA) receiver, comprising a receiver input for coupling to signal outputs of  $N_{rx}$  receive antennas, the signal outputs being sampled at  $N_s$  samples per symbol or chip, a matched filter, and a whitening filter system for coupling the receiver input to an input of the matched filter, said whitening filter system comprising  $N_s N_{rx}$  parallel individual whitening filters  $w_{j,k}$ , individual whitening filters  $w_{j,k}$  receiving, during each symbol interval  $I$ ,  $N_s N_{rx}$  new signal samples via a signal connection matrix such that a first individual whitening filter receives one of the new samples, a second individual whitening filter receives the same new sample as the first individual whitening filter, and one additional new sample, and such that an  $n$ th individual whitening filter receives the same  $n-1$  new samples as the first  $n-1$  individual whitening filters, plus one additional new sample, said whitening filter system comprising  $N_{rx}$  outputs for outputting filtered signal samples such that a filtered signal sample appearing in the  $N_{rx}$  outputs does not correlate with any other filtered signal sample appearing in  $N_{rx}$  outputs.
2. (Original) A CDMA receiver as in claim 1, further comprising a delay line comprised of a plurality of serially coupled delay line elements each having a delay of one symbol interval, said delay line having an input coupled to an output of said signal connection matrix and providing the  $N_s N_{rx}$  parallel whitening filters  $w_{j,k}$  with delayed versions of said signal samples.
3. (Original) A CDMA receiver as in claim 2, where for a symbol interval  $i$  and where  $N_s N_{rx} = 4$ , signal vectors output from the delay line elements are defined as:

$$\mathbf{r}(i-1) = \begin{pmatrix} r_{1,1}(i-1) \\ r_{1,2}(i-1) \\ r_{2,1}(i-1) \\ r_{2,2}(i-1) \end{pmatrix},$$

where in the term  $r_{n,m}(i)$  the symbols  $n$  and  $m$  denote an antenna and a symbol sample index, respectively, where an the input signal vector for an arbitrary one of the individual whitening filters  $\mathbf{w}_{n,m}$  is denoted by  $\mathbf{r}_{n,m}$ , the signal connection matrix results in input signal vectors:

$$\mathbf{r}_{1,1}(i) = \begin{pmatrix} \vdots \\ \mathbf{r}(i-2) \\ \mathbf{r}(i-1) \\ r_{1,1}(i) \end{pmatrix} ; \mathbf{r}_{1,2}(i) = \begin{pmatrix} \vdots \\ \mathbf{r}(i-2) \\ \mathbf{r}(i-1) \\ r_{1,1}(i) \\ r_{1,2}(i) \end{pmatrix} ; \mathbf{r}_{2,1}(i) = \begin{pmatrix} \vdots \\ \mathbf{r}(i-2) \\ \mathbf{r}(i-1) \\ r_{1,1}(i) \\ r_{1,2}(i) \\ r_{2,1}(i) \end{pmatrix} ; \mathbf{r}_{2,2}(i) = \begin{pmatrix} \vdots \\ \mathbf{r}(i-2) \\ \mathbf{r}(i-1) \\ \mathbf{r}(i) \end{pmatrix}$$

at the inputs to the individual whitening filters  $\mathbf{w}_{n,m}$ .

4. (Original) A CDMA receiver as in claim 3, where in a direct form solution, taking one of the signal vectors the signal model is expressed as

$$\mathbf{r}_{n,m}(i) = \mathbf{G}\mathbf{b} + \mathbf{n} = \begin{pmatrix} \mathbf{H} \\ \mathbf{h}^T \end{pmatrix} \mathbf{b} + \mathbf{n},$$

where  $(\cdot)^T$  denotes transposition,  $\mathbf{G}$  is a channel matrix, possibly including the effect of transmitter and receiver filters,  $\mathbf{b}$  is a symbol vector and  $\mathbf{n}$  a noise vector, and vector  $\mathbf{h}^T$  is the bottom row of  $\mathbf{G}$ , the corresponding individual whitening filter  $\mathbf{w}_{n,m}$  output is

$$g_{n,m}(i) = \mathbf{w}_{n,m}^H(i) \mathbf{r}_{n,m}(i),$$

where  $(\cdot)^H$  denotes conjugate transposition.

5. (Original) A CDMA receiver as in claim 4, where an individual whitening filter  $\mathbf{w}_{n,m}$  is obtained by using linear minimum mean-square error (LMMSE) criterion as

$$\mathbf{w}_{n,m}(i) = \begin{pmatrix} -\alpha \mathbf{C}_{n,m}^{-1} \mathbf{H} \mathbf{h}^* \\ 1 \end{pmatrix} = \begin{pmatrix} -\mathbf{u}_{n,m} \\ 1 \end{pmatrix},$$

in which  $(\cdot)^{-1}$  denotes matrix inversion and  $(\cdot)^*$  complex conjugation, where symbol  $\alpha$  is a real scaling factor, and the covariance matrix of  $\mathbf{r}_{n,m}(i)$  is

$$\mathbf{C}_{n,m} = \text{Expectation}\{\tilde{\mathbf{r}}_{n,m}(i)\tilde{\mathbf{r}}_{n,m}^H(i)\},$$

where the tilde above vector  $\mathbf{r}_{n,m}(i)$  denotes an operation where the bottom element of the original vector is excluded.

6. (Original) A CDMA receiver as in claim 5, where the unfixed part  $\mathbf{u}_{n,m}$  of the whitening filter is made adaptive in accordance with:

$$\mathbf{u}_{n,m} \leftarrow \mathbf{u}_{n,m} + \mu \{g_{n,m}^*(i)\tilde{\mathbf{r}}_{n,m}(i)\},$$

where parameter  $\mu$  is a step size factor.

7. (Currently Amended) A CDMA receiver as in claim 1, where said whitening filter system comprises is implemented using serially coupled lattice stages that form a lattice filter.

8. (Currently Amended) A method for operating a code division, multiple access (CDMA) receiver, comprising:

coupling a receiver input to signal outputs of  $N_{rx}$  receive antennas, the signal outputs being sampled at  $N_s$  samples per symbol,

whitening the signal outputs; and

filtering the whitened signal outputs with a matched filter, where

whitening uses a whitening filter system comprising  $N_s N_{rx}$  parallel individual whitening filters  $w_{j,k}$ , individual whitening filters  $w_{j,k}$  receiving during each symbol interval  $i$ ,  $N_s N_{rx}$  new signal samples via a signal connection matrix such that a first individual whitening filter receives only one of the new samples, a second individual whitening filter receives the same sample as the first individual whitening filter, and one additional sample, and such that an  $n$ th individual whitening filter receives the same  $n-1$  samples as the first  $n-1$  individual whitening filters, plus one of the remaining samples, and outputting from said whitening filter system, over  $N_{rx}$  outputs, filtered signal samples such that a filtered signal sample appearing in the  $N_{rx}$  outputs does not correlate with any other filtered signal sample appearing in  $N_{rx}$  outputs.

9. (Original) A method as in claim 8, further comprising operating a delay line comprised of a plurality of serially coupled delay line elements each having a delay of one symbol interval, said delay line having an input coupled to an output of said signal connection matrix and providing the  $N_s N_{rx}$  parallel whitening filters  $w_{j,k}$  with delayed versions of said signal samples.

10. (Original) A method as in claim 9, where for a symbol interval  $i$  and where  $N_s N_{rx} = 4$ , signal vectors output from the delay line elements are defined as:

$$\mathbf{r}(i-1) = \begin{pmatrix} r_{1,1}(i-1) \\ r_{1,2}(i-1) \\ r_{2,1}(i-1) \\ r_{2,2}(i-1) \end{pmatrix},$$

where in the term  $r_{n,m}(i)$  the symbols  $n$  and  $m$  denote an antenna and a symbol sample index, respectively, where an the input signal vector for an arbitrary one of the individual whitening filters  $\mathbf{w}_{n,m}$  is denoted by  $\mathbf{r}_{n,m}$ , the signal connection matrix results in input signal vectors:

$$\mathbf{r}_{1,1}(i) = \begin{pmatrix} \vdots \\ \mathbf{r}(i-2) \\ \mathbf{r}(i-1) \\ r_{1,1}(i) \end{pmatrix} ; \mathbf{r}_{1,2}(i) = \begin{pmatrix} \vdots \\ \mathbf{r}(i-2) \\ \mathbf{r}(i-1) \\ r_{1,1}(i) \\ r_{1,2}(i) \end{pmatrix} ; \mathbf{r}_{2,1}(i) = \begin{pmatrix} \vdots \\ \mathbf{r}(i-2) \\ \mathbf{r}(i-1) \\ r_{1,1}(i) \\ r_{1,2}(i) \\ r_{2,1}(i) \end{pmatrix} ; \mathbf{r}_{2,2}(i) = \begin{pmatrix} \vdots \\ \mathbf{r}(i-2) \\ \mathbf{r}(i-1) \\ \mathbf{r}(i) \end{pmatrix}$$

at the inputs to the individual whitening filters  $\mathbf{w}_{n,m}$ .

11. (Original) A method as in claim 10, where in a direct form solution, taking one of the signal vectors the signal model is expressed as

$$\mathbf{r}_{n,m}(i) = \mathbf{G}\mathbf{b} + \mathbf{n} = \begin{pmatrix} \mathbf{H} \\ \mathbf{h}^T \end{pmatrix} \mathbf{b} + \mathbf{n},$$

where  $(\cdot)^T$  denotes transposition,  $\mathbf{G}$  is a channel matrix, possibly including the effect of transmitter and receiver filters,  $\mathbf{b}$  is a symbol vector and  $\mathbf{n}$  a noise vector, and vector  $\mathbf{h}^T$  is the bottom row of  $\mathbf{G}$ , the corresponding individual whitening filter  $\mathbf{w}_{n,m}$  output is

$$g_{n,m}(i) = \mathbf{w}_{n,m}^H(i) \mathbf{r}_{n,m}(i),$$

where  $(\cdot)^H$  denotes conjugate transposition.

12. (Original) A method as in claim 11, where an individual whitening filter  $\mathbf{w}_{n,m}$  is obtained by using linear minimum mean-square error (LMMSE) criterion as

$$\mathbf{w}_{n,m}(i) = \begin{pmatrix} -\alpha \mathbf{C}_{n,m}^{-1} \mathbf{H} \mathbf{h}^* \\ 1 \end{pmatrix} = \begin{pmatrix} -\mathbf{u}_{n,m} \\ 1 \end{pmatrix},$$

in which  $(\cdot)^{-1}$  denotes matrix inversion and  $(\cdot)^*$  complex conjugation, where symbol  $\alpha$  is a real scaling factor, and the covariance matrix of  $\mathbf{r}_{n,m}(i)$  is

$$\mathbf{C}_{n,m} = \text{Expectation}\{\tilde{\mathbf{r}}_{n,m}(i)\tilde{\mathbf{r}}_{n,m}^H(i)\},$$

where the tilde above vector  $\mathbf{r}_{n,m}(i)$  denotes an operation where the bottom element of the original vector is excluded.

13. (Original) A method as in claim 12, where the unfixed part  $\mathbf{u}_{n,m}$  of the whitening filter is made adaptive in accordance with:

$$\mathbf{u}_{n,m} \leftarrow \mathbf{u}_{n,m} + \mu \{g_{n,m}^*(i)\tilde{\mathbf{r}}_{n,m}(i)\},$$

where parameter  $\mu$  is a step size factor.

14. (Currently Amended) A method as in claim 7 8, where said whitening filter system comprises is implemented using serially coupled lattice stages that form a lattice filter.

15. (Currently Amended) A code division, multiple access (CDMA) mobile station, said mobile station comprising a receiver coupled to  $N_{rx}$  receive antennas and further comprising baseband circuitry for sampling signal outputs of said  $N_{rx}$  receive antennas at  $N_s$  samples per symbol or chip, said baseband circuitry further comprising a multi-antenna RAKE receiver and a whitening filter system for coupling the sampled signals to inputs of said multi-antenna RAKE receiver, said whitening filter system comprising  $N_s N_{rx}$  parallel individual whitening filters  $\mathbf{w}_{j,k}$ , individual whitening filters  $\mathbf{w}_{j,k}$  receiving, during each symbol interval  $I$ ,  $N_s N_{rx}$  new signal samples via a signal connection matrix such that a first individual whitening filter receives one of the new

samples, a second individual whitening filter receives the same new sample as the first individual whitening filter, and one additional new sample, and such that an  $n$ th individual whitening filter receives the same  $n-1$  new samples as the first  $n-1$  individual whitening filters, plus one additional new sample, further comprising a delay line comprised of a plurality of serially coupled delay line elements each having a delay of one symbol interval, said delay line having an input coupled to an output of said signal connection matrix and providing the  $N_s N_{rx}$  parallel individual whitening filters  $w_{j,k}$  with delayed versions of said signal samples, said whitening filter system comprising  $N_{rx}$  outputs for outputting whitened filtered signal samples to said multi-antenna RAKE receiver.

16. (Currently Amended) A CDMA mobile station as in claim 15, where said whitening filter and said multi-antenna RAKE receiver together comprise a linear (~~minimum mean square error~~) channel equalizer.

17. (Currently Amended) A CDMA mobile station as in claim 15, where said whitening filter system and said multi-antenna RAKE receiver together comprise a multi-antenna space-time equalizer that optimally performs beam-forming while suppressing inter-cell interference.

18. (Currently Amended) A CDMA mobile station as in claim 15, where said same whitening filter system is used for receiving transmissions from a plurality of base stations during a soft handoff procedure.

19. (New) A CDMA mobile station as in claim 16, where said linear channel equalizer is comprised of a minimum mean-square error channel equalizer.

20. (New) A circuit, comprising an input for coupling to signal outputs of  $N_{rx}$  receive antennas, means for sampling the signal outputs at  $N_s$  samples per symbol or chip, matched filter means and whitening filter means for coupling the receiver input to an input of the matched filter means, said whitening filter means comprising  $N_s N_{rx}$  parallel individual whitening filters  $w_{j,k}$ , individual whitening filters  $w_{j,k}$  receiving, during each symbol interval  $I$ ,  $N_s N_{rx}$  new signal samples such that

a first individual whitening filter receives one of the new samples, a second individual whitening filter receives the same new sample as the first individual whitening filter, and one additional new sample, and such that an  $n$ th individual whitening filter receives the same  $n-1$  new samples as the first  $n-1$  individual whitening filters, plus one additional new sample, said whitening filter means comprising  $N_{rx}$  outputs for outputting filtered signal samples such that a filtered signal sample appearing in the  $N_{rx}$  outputs does not correlate with any other filtered signal sample appearing in  $N_{rx}$  outputs.

21. (New) A circuit as in claim 20, further comprising delay means comprised of a plurality of delay elements for providing the  $N_s N_{rx}$  parallel whitening filters  $w_{j,k}$  with delayed versions of said signal samples.

22. (New) A circuit as in claim 20, where said whitening filter means comprises serially coupled lattice stages that form lattice filter means.

23. (New) A computer program product comprising instructions operable for whitening a signal, comprising operations of:

operating on sampled signal outputs of  $N_{rx}$  receive antennas, where the signal outputs are sampled at  $N_s$  samples per symbol, for whitening the signal outputs, where whitening uses a whitening filter system comprising  $N_s N_{rx}$  parallel whitening filters  $w_{j,k}$ , individual whitening filters  $w_{j,k}$  receiving during each symbol interval  $i$ ,  $N_s N_{rx}$  new signal samples such that a first individual whitening filter receives only one of the new samples, a second individual whitening filter receives the same sample as the first individual whitening filter, and one additional sample, and such that an  $n$ th individual whitening filter receives the same  $n-1$  samples as the first  $n-1$  individual whitening filters, plus one of the remaining samples, and outputting from said whitening filter system, over  $N_{rx}$  outputs, filtered signal samples such that a filtered signal sample appearing in the  $N_{rx}$  outputs does not correlate with another filtered signal sample appearing in  $N_{rx}$  outputs.

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24. (New) A computer program product as in claim 23, further comprising operations of providing the  $N_s N_{rx}$  parallel whitening filters  $w_{j,k}$  with delayed versions of said signal samples.